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COSTS OF OPERATING AN INVENTORY SYSTEM WITH INACCURATE RECORDS

WILLIAM EDWARD DAESCHNER

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COSTS OF OPERATING AN INVENTORY SYSTEM WITH INACCURATE RECORDS

by

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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ABSTRACT

Changes in costs and in several effectiveness measures due to the introduction of errors into inventory records are investigated using Monte Carlo computer simulation of a multiple item, single warehouse, single inventory manager inventory system operating under a procurement budget constraint. Demands are generated using a "stuttering Poisson" stochastic process and transactions are processed on a daily basis. Parameters for the stochastic processes are obtained from line item input data by the method of moments. Stock is reordered using U. S. Navy UICP decision rules; stochastic lead times are generated for each order. Discrepancies of various types are introduced at rates reflecting estimates obtained from a large naval supply center. Changes in costs due to discrepant records are found to be significantly large. Comments are offered on the selection of a measure of effectiveness and its relationship to the decision making process. Suggestions are made for subsequent research.

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CHAPTER 1

INTRODUCTION TO THE PROBLEM

1.1 Inventory Record Accuracy

It has been asserted that some of the most successful applications of operations research techniques have been in the field of inventory theory. There is an extensive body of literature in the field, ranging from intuitive guidelines for managers to esoteric mathematical treatises. Generally, the problem formulations have as their objective the derivation of decision rules to determine when to buy stock and how much to buy for the various items in the inventory. The resulting decision rules are applied to the inventory through inventory records. For example, in the rule "down to four, order more," we mean that when our actual on hand inventory falls to a quantity of four, we should reorder. In practice we generally do not check the physical quantity on hand before reordering; rather, we maintain records of our inventory and reorder when our records indicate that we are "down to four."

An inventory manager hopes that there is good correspondence between the state of affairs implied by his records and the physical state of affairs in the warehouse. If this is not the case, predictions of effectiveness and of other results of actions taken based on inventory theory's decision rules, whether homely or sophisticated, may be invalid. Accurate inventory records have a certain value to the inventory manager; there are, also costs involved in increasing the accuracy of the records. It seems appropriate to investigate not only the allocation of dollar resources in a procurement budget versus procurement workload scenario, but also the allocation of resources to the improvement of record accuracy. The inventory manager typically is able to divert some resources into a physical inventory process whereby material is counted, the totals compared with record balances, discrepancies investigated and adjustments made to the records as appropriate. To date, not much information has been available to the inventory manager to assist him in deciding how much such physical inventory effort he should pursue, or how to conduct it, in order to best perform his function. In order to be able to make sensible decisions in this matter, one needs to know the costs of operating a supply system which has inaccurate records. We address the problem of quantifying these costs.

There are many possible consequences to inaccuracy of records; some are subtle. It is difficult to approach analytically the problem of quantifying the costs of operating an inventory system with inaccurate records. It seems that one can treat analytically gross oversimplifications of a real system or one can proceed through simulation to study experimentally a somewhat more plausible model of a real system. We have chosen the latter.

On the one hand, we have modeled a system of multiple items with interactions of members of different families of random variables; on the other hand, we wish to study the effects of the dependencies introduced when a procurement budget constraint is superimposed on a system using the modified Wilson economic procurement order rules of the U. S. Navy Uniform Inventory Control Point (UICP) system.

The meaning of "inventory record error" and possible measures of error in inventory records are discussed by Schrady [1]. Throughout this paper we use the term inventory record error or discrepancy to mean the non-agreement of the quantity of an item shown in the appropriate stock record to be available for issue with the quantity in the warehouse actually available for issue.

Positive inventory record errors have been defined as those where the actual on hand quantity exceeds the record quantity; similarly, negative errors describe a condition where there is less material available for issue than the records indicate [2]. We use this convention.

1.2 Navy Impact

For some time the General Accounting Office has expressed concern with the ability of the armed forces to account for inventories of materials [3]. Increasing concern has been exhibited for the impact of stock record inaccuracies on the ability of U. S. Navy stock points to perform their fleet support mission [4]. Recently, the Commander of the U. S. Navy Supply Systems Command elevated the inventory record accuracy problem to a position of first priority on the "Tough Ten" list of management problems in the command. At the time of this report, the problem is, also, number one on the "Top 20" list of the Chief of Naval Material.

1.3 Generation of and Discovery of Errors

Discrepancies are generated in inventory records through actions which cause changes in the physical quantity of material and those actions which cause changes in the record on-hand quantity. In particular, discrepancies are introduced in the processes of receiving and issuing material, as well as by unauthorized removals of material or unposted receipts of material. Additionally, discrepancies may be generated in adjustments of records for various reasons including, conspicuously, those resulting from the physical inventory process.

Discrepancies are discovered in the physical inventory process as well as by the occurrence of a warehouse denial of an issue request in the case when the records indicate that sufficient material is available for issue. Other notification of discrepancies may take place through stock location audit efforts.

In an early study of inventory record inaccuracies, Rinehart concluded that the policy of conducting shut-down wall-to-wall inventories and then adjusting records to agree with the inventory count (without investigation if the value of adjustment was less than the cost of an investigation) had produced about eighty per cent of the errors detected in a thorough post-inventory investigation [5]. A subsequent investigation of the U. S. Navy Research and Development Facility, Bayonne, concluded that the two primary causes for inventory record inaccuracies were the physical inventory process and normal, imperfect stock point operations [2].

This latter study concluded that immediately after a wall-to-wall shut down inventory, only about ninety per cent of the stock records might be correct (with respect, of course, to the on hand quantity); the per cent of records accurate with respect to this one data field then was found to decline at a decreasing rate to an estimated figure of about seventy per cent at the end of four years. It was then hypothesized that seventy per cent was an approximate equilibrium point for the activity being studied due to the corrective action of the various special inventories which were taken. The report, also, indicated that the number of demands experienced by a stock record is a useful indicator of error expectation in the record.

1.4 Effects of Errors

A positive error in the record of an item of stock tends to cause a reorder to be placed for the item in question too soon. Too soon means that we might prefer to delay the reorder of this item if we knew the true situation. Because we are not aware that we have the discrepant quantity on hand, we may needlessly backorder material. Thus, positive errors tend to increase the value of inventory carried without increasing the effectiveness attained by the stock point.

Negative errors result in greater risk of running out of stock than was believed to exist, for they tend to delay reordering. They result in warehouse refusals which require exceptional treatment in the processing system and cause undesirable delays in servicing the customer.

These effects seem especially serious in the case of severe constraints on procurement budgets and long lead times for material. In such a case, the spending of money in buying stock for an item with positive error may result in an insufficiency of funds to reorder another item. Long lead times may result in lengthy backorders when negative errors are discovered even with funds available in the procurement budget.

CHAPTER 2

THE MODEL

2.1 General Approach

We have constructed a modular mathematical model of the system and have reduced the model to a FORTRAN IV language computer program. We use the Monte Carlo simulation technique [6, 7]. Our model simulates operations one day at a time and prints reports at specified intervals. Its modular nature permits the use of a variety of demand generators, as well as modifications of the lead-time distribution assumptions, budget computation and availability procedures, ordering decision rules, as well as the rate and variety of discrepancy generation. For the experiment being performed, each stock record carries two on hand quantity data fields; one contains the recorded quantity, while the other holds the actual quantity on hand. Reorder actions are based upon the recorded quantities. Requisition arrivals initiate issue action only when the "records" indicate that some stock is on hand. The quantity issued, however, cannot exceed the actual on-hand quantity. We employ two pseudo-random number generators; one for demand generation and the other for all other Monte Carlo requirements. Thus we are able to reproduce the same random numbers in the demand generator in different runs.

2.2 System Modeled

The supply system we have chosen to model operates on an issue preposting system so that material is not issued from stock unless the records indicate that some material is available for issue. This system is prevalent at stock points of the U. S. Navy Supply Systemd Command and is in contrast to a postposting system in which issues are posted to stock records subsequent to the physical issue of material. We treat receipts as being posted and made physically available for issue at the same time. The system is treated as a single inventory manager, single warehouse, multi-item system operating under a procurement budget constraint. All shortages are backordered.

It is believed that the model represents reasonably well the processing system at a typical naval stock point. The experimenter has the experience of duty at two U. S. Naval Supply Depots and has some familiarity with processing of receipts and issues, having served both as Receipt Control Division Director and Issue Control (and later, Customer Service) Division Director.

Demands (simulated requisitions) are generated in accordance with a "stuttering Poisson" stochastic process; that is, the time between requisition arrivals is distributed as an exponentially distributed random variable, while the quantity demanded on an individual requisition is distributed as a geometrically distributed random variable.

2.3 Functional Description of Processing Routines

During the daily processing routine, the day's receipts are batch-posted at the beginning of each day. Next, backorders are released for those items having stock on hand. Finally, each item is sequentially examined to determine whether any demands will be received on the current date. If so, all such requests are processed in turn. Spot inventories are conducted when there is a warehouse denial, which occurs when the actual on-hand quantity is less than the attempted issue quantity. Whenever the budget permits and the inventory position, defined as the sum of record on-hand quantity and quantity on order minus the sum of the quantity currently being demanded and the quantity backordered, does not exceed the reorder point found in the "CARES ANALYZER" output, an order is placed for the smallest multiple of the reorder quantity shown in the same output which causes the inventory position to exceed the reorder point. The lead times for reorder material are assumed to be random variables, normally distributed with mean given by the "CARES ANALYZER" output and with standard deviation equal to .29 times the mean lead time. Lead times are truncated, in any case, to be not less than one day or more than 2.74 times the mean lead time. If there are insufficient uncommitted funds in the procurement budget to provide for an order, no order is placed. Additionally, on the first day of each year, after the new budget has been received, each stock record is scanned and reorders are placed in multiples of the item reorder quantity as needed to raise the inventory position above the reorder point, provided the new budget so permits.

Discrepancies are introduced by Monte Carlo mechanisms in the processes of issuing and receiving material. Initially, all records agree with the actual situation. Discrepancies may be resolved through the mechanism of a "spot inventory" which is taken to mean a physical inventory of a single line item. Discrepancies are introduced in the course of accomplishing issues, receipts or spot inventories. Discrepancies occur in a number of varieties, at parameterized relative rates simulating those experienced at a large U. S. Naval Supply Center. The spot inventory correction rate is similarly parameterized. Statistics are accumulated on unit days backordered, requisition fill effectiveness, unit-days stock held, number of procurement orders initiated, number of receipts processed, number of spot inventories taken, number of warehouse refusals, number of discrepancies generated or corrected in the processes of issuing, receiving or inventorying, and value of stock procurements.

2.4 Main Program Control System

The investigator is aware of two general approaches to main program control of computer simulation which might have been used in the current problem. The first approach has been called "event-store" and is somewhat similar in approach to maintaining a stack of work items in a multi-level incoming basket containing one work item per level. Whenever a new work item is to be added to the stack, one must decide where in the stack it should be inserted and then insert that item and move items that will be done subsequent to the new item to positions one step farther removed from the top. Work items are performed only after they reach the top of the basket. As one might imagine, quite a bit of shuffling might result if several thousand items were to be stored.

The second approach is somewhat like maintaining a list of work items on a calendar pad on the date they are to be performed. Whenever a new work item is to be stored for future action, it is listed on the page of the calendar pad corresponding to the day on which the action is to take place. Each day the items to be performed on that day are executed in some arbitrary sequence. This second concept has been called "time step" program control. It has a disadvantage in that the whole sheet of the calendar pad must be scanned each time step unit whether or not any work is to be done that day.

The technique finally selected was a combination of a modified event-store control on requisition processing, storing only the computed time of the next requisition arrival in each stock record, and time step on receipt processing and main program control.

2.5 Discrepancy Generation and Correction

In using the Monte Carlo simulation technique, whenever material is received, a pseudorandom number is generated. The value of this number determines first of all whether the quantity actually received is greater than, or less than, the quantity ordered by a specified percentage; the resulting quantity thus computed to be physically received is truncated to an integer value and posted accurately to the record on-hand field as well as the actual on-hand field of the item record. If the correct quantity was received, the random number determines whether it is posted accurately to the record on-hand quantity field. Provision is made for posting the correct quantity to an incorrect record, determined at random by the value of the random number. The relative frequency of each of these occurrences as well as the percentage deviations of a quantity received are controlled through parameters which remain fixed throughout each run. The same set of parameters governs such events for all items in the inventory.

Somewhat similarly, in the issue process the random number determines whether the correct quantity is issued, whether nothing is actually issued or whether the quantity issued varies from the requisition quantity by various amounts of either underissue or overissue. Again, relative magnitudes and relative frequencies are determined by system parameters which are held fixed over a run.

In the spot inventory process, the random number determines whether the spot inventory being conducted results in the record on-hand quantity being set equal to the actual on-hand quantity or whether the discrepancy remains unaffected by the spot inventory.

2.6 Budget Constraint Treatment

The procurement budget is believed to be the primary constraint perceived by the military inventory manager. The constraint is seen to affect the reorder decision rules in two ways. First of all, the constraint is reflected in the decision rules (such as reorder quantity and reorder point) used by the inventory manager. A second effect of the constraint is a familiar vernal phenomenon -- no dollars are available for stock procurement. It was desired to include in the model the capability of observing both manifestations of the procurement budget constraint. A single parameter controls the number of dollars available by acting as a multiplicative constant which is then multiplied times the value of mean forecast annual demand, computed from the input data. A single setting of this parameter was used through the experiments which were performed. Each run of the experiments described in Chapter 3 operated with the same demand parameters, same starting point and same budget. The range of dates when the budget balance was first insufficient to fund an indicated buy varied from (considering that the simulation commenced at the start of a fiscal year, on 1 July) a simulated 19th of February at the earliest through the end of June (meaning, in the latter instance, that there was always enough money uncommitted to order the indicated order quantity when we hit a reorder point). The average of day 309 found in Table 1 would correspond to the fifth of May on a fiscal year basis.

CHAPTER 3

EXPERIMENTS CONDUCTED

3.1 Description of Runs

Two experiments were conducted using the model discussed in Chapter 2. The first sought to simulate operations for a period of five years in order to measure the decline of record accuracy with time, and to compare attained effectiveness and costs with those of an error-free system. In the other experiment, we explore the impact on second year costs and effectiveness measures of the perfect conducting of a complete physical inventory at the beginning of the second year.

The first experiment consisted of simulating five years operations of an inventory of one hundred items. Initially, each record accurately reflects the asset situation. A budget for procurement of stock is made available at the beginning of each year. At the end of each year, the records are printed along with summary statistics. Five years were thus simulated. The experiment was repeated with three different parameter sets including one (IA) which caused perfect accuracy of operations, a second set (IB) reflecting those measured and estimated at a large U. S. Naval Supply Center, and a third set (IC) causing different discrepancies (of the same relative frequencies) to be generated at twice the rate of the second set. Three replications using different random number sequences were obtained.

The second experiment gathered data on various performance indices during a simulated two years of operations in which the same random numbers were used in three passes. In the first pass (IIA), the parameters were set to insure that no record discrepancies would occur. In the second (IIB) and third passes (IIC), the parameters were those of our simulated naval supply center; distinguishing the second and third passes is the decision in the second pass to conduct a complete physical inventory at the beginning of the second year while the third pass was conducted, as in the first, experiment, without such all-items inventories. The complete physical inventory was assumed to be conducted without error so that records were all accurate at the beginning of the second year.

3.2 Data Sources

Data for the individual records was obtained by making two replications of item data taken from the fifty (1H-cognizance) U. S. Navy ships repair parts estimated to require the greatest procurement expenditure in the year following a 26 September 1967 run of the "CARES ANALYZER" program at the U. S. Navy Fleet Material Support Office, Mechanicsburg, Pennsylvania. The two parameters needed to describe the individual "stuttering Poisson" stochastic process are obtained by the method of equating probabilistic moments using the estimates of mean item demand in a quarter, mean lead times, and standard deviation of demand in a lead time obtained from the "CARES ANALYZER" output. Results given by Parzen [8] for the first two central probabilistic moments of a compound Poisson stochastic process provide the necessary mathematical formula for computing the value of the parameters to be used. In general, each line item will have different parameters. A more complete discussion of techniques used may be found in Appendix A.

It is emphasized that the input data is taken from a (non-ramdom) select group of items with a demand history indicating that they place very high monetary requirements on the inventory system. Additionally, the selection implies that their system asset position at the beginning of the simulation was relatively low.

Through the cooperation of the Commanding Officer of the large U. S. Naval Supply Center in Oakland, California and particularly the Quality Control Division Director, Mr. Robert E. Carter, estimates of the rates of introduction of discrepancies in stock records were obtained. These estimates included principally the rates attained in the processes of receiving and issuing material, and included such data as the estimated frequency of posting a receipt to the wrong record, over-issuing by an amount of between ten and twenty per cent in excess of the correct quantity, etc.

In our simulated "normal" supply center, the following key parameters were used in both Experiment I and Experiment II:

Event	Probability
Spot inventory corrects discrepancy	.97
Receipt processed perfectly	.96
Receipt posted to randomly selected record	.01

Event	Probability
Receipt of less than documented	.015
Receipt of more than documented	.015
Issue conducted perfectly	.98
Failed to issue	.0068
Overissue	.0066
Underissue	.0066

CHAPTER 4

RESULTS OBTAINED

In Table I, we observe an error rate varying in time much as was hypothesized by the U. S. Navy Research and Development Facility, Bayonne [2]. We observe that errors increased somewhat more rapidly and did not level off so quickly as extrapolated by the Bayonne study. The items in our study tended to be unusually active items; with errors introduced by receipts and issues, we expect faster growth of error rate in our sample than in a typical inventory, as may be inferred from the Bayonne report. We conducted spot inventories on a minimal level. Added investment in inventory effort should slow the increase in error rate and tend to raise the equilibrium error rate. We started with completely accurate records; this factor would tend to make our results artificially favorable. We believe that the net effect may be to make our attained accuracy figures move toward equilibrium slightly faster than a typical system conducting physical inventories on the same basis. It was especially interesting to note that of the individual records which were not in error, about sixty per cent indicated a correct balance of zero. This is not surprising since we conducted spot inventories only upon having a warehouse refusal.

In Experiment I, we also measured changes in various cost and effectiveness indices. In every experimental run, the error-free system outperformed the imperfect systems in the first year; similarly, in all but one run, the same ranking was observed in the second year.

TABLE I

SUMMARY RESULTS OF EXPERIMENT I (average of 3 replications)

Five Year Summary Figures	Standard	Performance Indices		
Measures:	Run IA	Run IA	Run IB	Run IC
# reqns filled completely	1121.5	1.	.968	.962
# reqns processed	2902.9	1.	1.	1.
# reqns filled at least partially	1206.0	1.	.977	.980
# warehouse refusals	0.	0.	5.54	8.14
# stock reorders placed	463.4	1.	1.024	1.005
Value of actual inventory at year end	$656382.00	1.	1.325	1.389
Average inventory held	$835997.00	1.	1.220	1.275
Day budget constraint first active	309	1.	.955	.937
Average units backordered	110881	1.	1.004	1.043
# spot inventories conducted	0	0	5.9	8.1
Per cent records accurate at end of year	Year 1	100	79.3	67.3
	Year 2	100	70.0	57.0
	Year 3	100	61.0	49.7
	Year 4	100	53.3	45.0
	Year 5	100	48.0	40.0

Standard figures given are for average year over the three replications.

Performance indices used are the quotient of the average performance of the parameter set over the three replications divided by the performance of the error-free system if the latter is not zero; otherwise the divisor is one.

Over the five year period of Experiment I, the requisition fill rate was cut between three and four per cent by having the NSC operation parameters, while the on-hand inventory increased by some 30 per cent. The procurement budget constraint was felt about one week earlier than the perfectly accurate system, and the grand total of unit-days backordered increased on the order of half a per cent.

Turning to Table II. we see that having perfectly accurate records at the start of the second year enabled our NSC system to cut a decrease of eight and one half per cent in requisitions filled to six per cent under the perfectly accurate system. The increase in unit-days backordered over the accurate system was cut from six and one half per cent to under five and one half per cent. The day procurement funds became inadequate to fund an indicated procurement was postponed by about nine days while the average on-hand inventory dropped by five per cent. The average on-hand inventory in the second year was cut five per cent by the perfect physical inventory to a level some 2.4 per cent less than that of the clean system.

TABLE II

SUMMARY RESULTS OF EXPERIMENT II

Measure	Year	Performance Indices		
		Run IIA	Run IIB	Run IIC
# reqns filled upon receipt	1	1	.981	.981
	2	1	.939	.916
# reqns filled at least partially	1	1	.990	.990
	2	1	.956	.922
# warehouse refusals	1	0	5.5	5.5
	2	0	4.5	5.5
# units backordered	1	1	1.008	1.008
	2	1	1.053	1.064
Day budget constraint first active	1	1	.994	.994
	2	1	.991	.971
# receipts in the year	1	1	1.000	1.000
	2	1	.998	1.016
# stock reorders in the year	1	1	1.003	1.003
	2	1	1.008	1.004
Value actual inventory at the end of the year	1	1	1.038	1.038
	2	1	1.006	1.125
Average on hand inventory value	1	1	1.006	1.006
	2	1	.976	1.026
# spot inventories conducted	1	0	5.5	5.5
	2	0	4.5	5.5
# complete inventories conducted	1	0	0	0
	2	0	1	0
Per cent records accurate at end of year	1	100	81	81
	2	100	79.5	73.5

The total inventory contained 100 items. A total of all 11,629 requisitions were processed in each run, counting both replications.

Performance indices used are the quotient of the average performance of the run over the two replications divided by the performance of the error-free system if the latter is not zero; otherwise the divisor is one.

CHAPTER 5

OBSERVATIONS AND CONCLUSIONS

5.1 Observations

A sizeable increase in actual on-hand inventory in runs IB and IC may be noted in Table 1 of Chapter 4. Explanation lies in the inherent advantage of an issue postposting system over an issue preposting system with respect to inventory record accuracy, all other things being equal. In an issue preposting system, the errors discovered without special inventory effort seem to be negative errors which are discovered by warehouse refusal of the issue request. An issue postposting system will discover positive errors by generating negative on-hand balances and will discover negative errors by refusals of issues when the records show a positive balance so long as all demands are recorded. The key difference in the systems is the fact that with issue preposting, the physical stock level is not checked in the routine course of business unless the records indicate stock is on hand. This phenomenon accounts for the sizeable increase in actual on-hand inventory of an imperfect preposting system over a period of time even when an equal number of over-issues and under-issues is made.

A management tool which should be simple to implement, cheap to use, and provide a payoff when it is most needed has suggested itself by the observation that on the order of forty per cent of the inaccurate records may have a zero balance on the record when there is actually material on hand.

A spot inventory rule based on a zero balance inventory has been used and discarded by the Navy. No doubt the fact that once a zero balance is attained it remains a zero balance as more requisitions are received until such time as material is received, had something to do with the dropping of this trigger. It is proposed that rather than flag a spot inventory, the computer flag material release documents on which a quantity is issued which draws the record on-hand quantity down to zero. The warehouseman making the actual breakout of material will know whether there are more bolts in the bin, or whatever, and could then request a spot inventory if a discrepancy is indicated. Such a policy might be used with care on pilferable items.

5.2 Measures of Effectiveness and Decision-Making

In a decision situation, an executive tries to weigh the potential results of his feasible alternate courses of action. He must arrive at some balance of costs and beneficial effects. If an action has a number of different effects, each of which is of importance to the decision-maker, there may be cases when one or more beneficial effects may be increased only at the expense of other effects for a given cost. More formally, there may be many efficient (in the economic sense) decisions. An analyst may seek to determine those efficient decisions whose anticipated results are equally acceptable to the executive, and which simultaneously are preferred to all other decisions (called optimal decisions). In order that the implied ranking may be accomplished by the analyst, he must know the relative desirability to the executive of all possible combinations of different levels of the various beneficial effects. In utility theoretic terms, the analyst must know the relevant preference surface of the executive.

In performing systems analysis, one typically chooses a measure of effectiveness or objective function through which one mathematically evaluates the utility or disutility of the various combinations of different levels of the anticipated effects of the decisions. The solution thus produced by the analyst and claimed as optimal may then be optimal so far as the measure of effectiveness is concerned, subject to the constraints imposed by the analyst. The executive may be able to determine that the measure of effectiveness chosen is an inadequate reflection of his relevant preference surface or that the constraints imposed by the analyst are not the constraints governing the actual problem. In such a case, the executive may throw out the analysis, require a reassessment by the analyst, hire a different analyst, or, at the least, make a decision while having significant unanswered questions.

For example, in an inventory control environment, the selected measure of effectiveness might be to maximize the expected number of requisitions filled, or to minimize the expected the expected number of unit days backordered, or to maximize the expected value of sales, or to minimize the expected number of reorders, or to maximize the expected number of units sold, or to minimize the average value of inventory held, etc. Similarly, we might find a large set of constraints which could be applied.

If an executive is asked to choose a measure of effectiveness from the examples above, he likely will want to hedge. He realizes that improving some of them at the expense of others may be undesirable; the implicit trade-offs among the measures are perceived, but dimly.

A common approach is to add constraints at some arbitrary level for those measures not selected for the measure of effectiveness. For example, one might attempt to minimize the expected number of unit days backordered subject to constraints on the procurement budget and on expected number of requisitions filled, and so on. Alternatively, one might attempt unconstrained optimization of several different measures of effectiveness and display the decision rules and the various projected effects for the executive. Additionally, one could successively employ various levels of constraints and observe the resultant effects. For instance, one might first attempt to minimize total annual variable costs subject to a constraint on number of expected backorders per year. Then, one might add a procurement budget constraint and solve this problem. Next, one might constrain the expected annual sales to be at least some assigned value. Successively, we insure that our solution has fewer possibilities of being unacceptable because of some performance index which is at an intolerable level.

The diehard economist may insist that we can impute dollar value to incommensurables involved in a decision so that the decision rules used will minimize total annual variable costs for such a system. Indeed, the calculation of imputed dollar costs can be of value to an executive faced with a multiplicity of fragmented budgets with which to operate his organization. The results of these calculations may suggest opportunities for savings through restructuring his budgets and removing some artificial constraints in favor of greater economy of operation.

It may be undesirable to have the analyst assign dollar costs to significant incommensurable factors in an analysis and present the executive with decision rules which are claimed to be optimal (with respect to the assumptions of the analyst). Rather, it is recommended that the analyst attempt to provide the executive with a set of several efficient alternatives, displaying for him the trade-offs among important indices of expected performance. Thus, the executive can have more than rubber stamp or dart-throwing importance in the decision-making process, and the resultant decisions trade-offs may be very nearly optimal from the executive's point of view.

Consider for a moment a homely illustration. Suppose you have a dime and want to buy a candy bar. Perhaps you have listed for a friend all the desirable properties of a candy bar that you could think of -- milk chocolate might be preferred to dark chocolate, almonds to peanuts, any kind of chocolate might be preferred to peanut butter flavor, and so forth. In the one case, your friend might carefully analyze the contents of the available candy bars, impute values to them, sum up the values of the various ingredients, choose the candy bar with the greatest computed value, and buy it for you. In the other case, your friend might narrow the field to three or four likely candidates by using your expressed desires and give you a choice of the few thus selected. It is believed that the latter procedure will generally result in a better decision; in any case, it may prevent the purchase of a coconut bar to which you are allergic, but which allergy you forgot to mention to your friend.

5.3 Conclusions

Because of the difficulties involved in assigning relative values to the various measures of performance, we have designed the experiment in such a manner that different valuations may be applied and costed out, if desired. We would calculate or impute average order costs, holding cost rates and shortage costs as well as physical inventory costs, multiply each cost factor by the difference in performance attained, and sum these quantities to get inventory system costs.

For the sake of example, the average changes in effectiveness observed in the various runs were priced out at \$42.00* per stock reorder, holding cost rate of .15* per dollar year of inventory held, shortage costs of \$10.00* per requisition not filled when it hits the system, free spot inventories, and both the rates of one cent and ten cents penalty for every day a unit is backordered.

In the first experiment, over a five year period of time, additional costs of \$224,400 were incurred in run IB over run

*Again, from "CARES ANALYZER" outputs

IA, with a daily shortage cost of one cent per unit day. At a dime per unit, the additional cost priced out at $951,300.

Using the same pricing system on the results of the second experiment resulted in additional costs in runs II B and II C of $3900, at one cent per unit backordered each day or $20,800 at a dime per unit, for the first year. The second year of run II B incurred additional costs of $17,200 at one cent and $189,000 at ten cents. In the second year, run II C incurred additional costs of $26,800 at one cent and $234,400 at one dime, over run II A.

To summarize,

		Daily Shortage Rate	
Run	Year	$ .01	$ .10
I A	1-5	U	V
I B	1-5	U + $224,400.00	V + $951,300.00
II A	1	W	X
	2	Y	Z
II B	1	W + $3900.00	X + $20,800.00
	2	Y + $17,200.00	Z + $189,000.00
II C	1	W + $3900.00	X + $20,800.00
		Y + $26,800.00	Z + $234,400.00

If the above valuations of performance degradation are accepted by an executive, he might conclude that inventory record inaccuracy was sufficiently expensive that he would explore various means of investing resources in controlling inventory record inaccuracy in such a manner that the costs of the control system would not exceed the ranges of costs summarized above. It is suggested that simulation of various control systems superimposed on an inventory system such as the one modeled in this system would be useful in predicting costs and benefits of various proposed systems. Considering the low costs of simulation with high-speed computers and the stakes involved in running a real inventory system, such research seems justified.

CHAPTER 6

SUGGESTIONS FOR FUTURE RESEARCH

It would be desirable to have an opportunity to compare the demand patterns produced by the "stuttering Poisson" process with empirical data. Unfortunately, most data on demand collected by the Navy deals with the quantity demanded in a period of time, usually a quarter year. In order to realistically simulate requisition processing and its impact on a supply activity, one needs to know more about the distribution of quantity demanded on a requisition. It does not seem realistic to model demand processes generating high average quarterly demands as having an average of one item demanded per requisition. Such is not consistent with our experience and may confound optimization attempts. Certainly, statements concerning requisitions fill effectiveness are sensitive to the distribution of the quantity demanded per requisition. It would be a relatively simple process to accumulate data on inter-arrival time and requisition quantity, but it is a laborious task to obtain past data by poring through old transaction ledgers. It is noted that Mr. B. Roseman, Director Inventory Research Office, Army Material Command Logistic Systems Support Center mentioned in a recent seminar at the U. S. Naval Postgraduate School that his office has found the "stuttering Poisson" to provide a good fit for many of the items of their interest.

The inventory simulator lends itself to generalization to a multi-echelon multi-warehouse system simulator with one or more inventory control points operating with one or more procurement budget constraints. Running time on the IBM 360-67 computer at the U. S. Naval Postgraduate School is about seven minutes including about one minute for compiling. The requisition size computations using the geometric distribution account for about one third of the running time, with another third used in the daily search of the receipt due file which, as currently programmed, involves 2500 comparisons per day. In five years, we have made over 4.6 million equality checks in this program segment. Run time on Experiment II was three and one-half minutes including compilation time. The simulator should be useful in the evaluation of various spot inventory trigger schemes. For this experiment, it might be desirable to have several hundred items, thus forming a larger and more representative sample inventory.

Periodic reviews could readily be incorporated in the model, thus providing for opportunities to study the efficacy of different forecasting techniques as well as various order rules. Handling of the budget might be made more realistic by providing a variable budget based on such factors as sales in the past period and current inventory position. It is easy to provide for trends in mean demands on both an item basis, and an inventory basis. An interesting experiment might be conducted with an inventory in which the mean demand of most items is increasing while the mean demand of other items is decreasing. The relationship of effectiveness measures to procurement budget levels might be explored along with the repercussions of delay in providing a budget when lead times are long.

BIBLIOGRAPHY

1. Schrady, David A., "On Inventory Record Accuracy," Report No. NPS55SO8031A, U. S. Naval Postgraduate School, March,1968.

2. U. S. Navy Supply Research and Development Facility, "Physical Inventory Procedures at Navy Stock Points," unpublished research report, 1966 (Available through Defense Documentation Center AD-488317).

3. General Accounting Office, "Improved Inventory Control Needed for the Department of the Army, Navy, and Air Force and the Defense Supply Agency," Report to Congress, November, 1967.

4. U. S. Navy Auditor General, "Accuracy of Navy and Marine Corps Stock Records," Service-Wide Audit Report IA1-65, 1965.

5. Rinehart, Robert F., "Effects and Causes of Discrepancies in Supply Operations," JORSA, Volume 8 # 4, 1960.

6. Hammersley, J. M. and D. C. Handscomb, "Monte Carlo Methods," London: Methuen & Co., 1964.

7. Golden, James T., "Fortran IV Programming and Computing," Englewood Cliffs, N. J.: Prentice-Hall, 1965.

8. Parzen, Emanuel, "Stochastic Processes," San Francisco: Holden-Day, 1962.

9. Brock, Leonard E., "An Appraisal of Asset Control Techniques as Applied in the Selective Management of High Value Secondary Aeronautical Items in the Department of the Navy, Unpublished Master's thesis, U. S. Naval Postgraduate School, 1964 (Available through Defense Documentation Center AD-480489).

10. Van Tol, Peter H. B., Jr., "A Study to Determine the Effect of Inventory Control and Accountability on Inventory Losses Due to Theft and Pilferage," Unpublished Master's thesis, U. S. Air Force Institute of Technology, 1964 (Available through Defense Documentation Center AD-805316).

11. Wright, Walter F., Jr., "A Review and Analysis of the Physical Inventory Process at Navy Stock Points," Unpublished Master's thesis, U. S. Naval Postgraduate School, 1965 (Available through Defense Documentation Center AD-475874).

APPENDIX A

The Stochastic Process Assumed to Underlie the Demand Process

Let the total quantity of item i demanded up to time t be denoted by $X_i(t)$ and let $X_i(t) = \sum_{n=1}^{N_i(t)} Y_{in}$, in which Y_{in} is the quantity demanded on the n^{th} requisition for item i and $N_i(t)$ is the number of requisitions received up to time t.

We assume $\{N_i(t),\ t \geq 0\}$ to be a Poisson process and we assume $\{Y_{in},\ n=1,2,\ldots,N_i(t)\}$ to be a family of independent identically distributed random variables distributed geometrically with probability pass function

$$\begin{aligned} p_Y(y) &= p(1-p)^{y-1} && \text{for } y=1,2,\ldots \\ &= 0, && \text{otherwise} \quad . \end{aligned}$$

The time between occurrences of requisition receipts for item i is distributed as an exponentially distributed random variable under the Poisson arrival assumption. The density function is given by

$$\begin{aligned} f_T(t) &= \nu e^{-\nu t} && \text{for } t \geq 0 \\ &= 0, && \text{otherwise.} \end{aligned}$$

A stochastic process such as $\{X(t)\}$ is termed a compound Poisson process; the particular compounding with a geometric distribution is sometimes called a "stuttering Poisson" process. It is shown by Parzen [8] that the compound Poisson process $\{X(t),\ t \geq 0\}$ has the following properties:

$$\Phi_{X_i(t)}(u) = e^{\nu t(\Phi_{Y_i}(u)-1)}$$

where $\Phi_{Y_i}(u)$ is the common characteristic function of the independent, identically distributed random variables $\{Y_{in}\}$ and ν_i is the mean rate of occurrence of the event that a requisition is received for item i; additionally,

$$E[X_i(t)] = \nu_i t E[Y_i]$$

$$\mathrm{Var}[X_i(t)] = \nu_i t E[Y_i^2]$$

$$\mathrm{Cov}[X_i(s), X_i(t)] = \nu_i E[Y_i^2] \min(s,t) \quad .$$

We observe that the mean/variance ratio of $X_i(t)$ is

$$E[Y_i]/E[Y_i^2] \quad .$$

Empirical estimates of data needed to compute mean/variance ratios of $X_i(t)$ are contained in the output of the CARES ANALYZER for time t equal to one leadtime estimate. It seems reasonable to hypothesize a distribution for Y_i which can assume the empirically estimated mean/variance ratios and which assumes values with positive probability only on the positive integers. The geometric distribution met these criteria and was selected. Note that

$$E[Y_i] = \frac{1}{p_i}$$

and

$$E[Y_i^2] = \frac{(1-p_i) + 1}{p_i^2} \quad .$$

In computing parameters to be used for an individual stock record we need to pick ν_i and p_i for each item. We do this by using the method of moments and the estimates of mean and standard deviation of demand in a lead time. For example, if we have an estimate $\tilde{\mu}_i$ of mean demand in a quarter and if our estimate of the lead time is $\tilde{\tau}_i$ quarters, then we estimate the mean demand in a lead time by $\tilde{\mu}_i\ \tilde{\tau}_i$. If we then have an estimate of $\tilde{\sigma}_i$ of the standard deviation of demand in a lead time we estimate the variance of quantity demanded in a lead time by $\tilde{\sigma}_i^2 = (\tilde{\sigma}_i)^2$. Since $E[X(t)] = \frac{\nu t}{p}$, dropping subscripts, and $VAR[X(t)] = \nu t\,\frac{2-p}{p^2}$, we estimate p by $\tilde{p} = 2/(1+\tilde{\sigma}^2/(\tilde{\mu}\tilde{\tau}))$ and ν by $\tilde{\nu} = \tilde{\mu}(2/(1+\tilde{\sigma}^2/(\tilde{\mu}\tilde{\tau})))$. These estimates are computed and stored in each stock record and are used in the computation of requisition inter-arrival times and requisition quantities for the various items.

EXAMPLE: FSN 1H 2050-395-4300

estimated lead time in days = 3.9 x 90 = 351

estimated mean demand in lead time = 81.8 x 3.90 = 319.02

estimated variance of quantity demanded in a lead time is $(87.8)^2 = 7708.84$

so $\tilde{p} = 2/(1 + (7708.84/319.02)) = 2/(1 + 24.1641) = .0794$

and $\tilde{\nu} = \frac{81.8(.0794)}{90} = .0722$ in units of (requisitions per day)

.0794 is then stored in field 16 and .0722 is stored in field 17 of the stock record of FSN 1H 2050-395-4300.

APPENDIX B

FORTRAN IV PROGRAM LISTING

```
      DIMENSION RECORD(1000,20),TRCPT(2,2500),IFSC(1000),IFIIN(1000)
C     RECORD(I,J) REFERS TO THE JTH FIELD OF THE STOCK RECORD OF THE ITH
C     ITEM.  THE FIELDS HOLD THE FOLLOWING DATA  1-BLANK, 2-UNIT PRICE.
C     3-RECORD ON HAND QUANTITY, 4-ACTUAL ON HAND QUANTITY, 5-DUES,
C     6-BACKORDERS, 7-REORDER QUANTITY,8-REORDER POINT, 9-MEAN QUARTERLY
C     DEMAND, 10-MEAN LEAD TIME, 11-TEME OF RECEIPT OF NEXT REQUISITION
C     12-ITEM ACTIVITY COUNTER, 13- QUANTITY ISSUED SO FAR
C     EXCLUDING BACKORDER RELEASES, 14-TOTAL QUANTITY DEMANDED SO FAR,
C     15-STANDARD DEVIATION OF LEAD TIME DEMAND, 16-DEMAND PARAMETER P,
C     17-DEMAND PARAMETER NU, 18-NUMBER OF UNIT-DAYS BACKORDERED SO FAR,
C     19 AND 20 ARE CURRENTLY UNASSIGNED.
C     IFSC(I) HOLDS THE FSC GROUP AND CLASS OF THE ITH ITEM.
C     IFIIN(I) HOLDS THE FEDERAL ITEM IDENTIFICATION NUMBER OF ITEM I.
C     TRCPT(1,J) HOLDS THE INDEX OF ARRAY RECORD(I,J) WHICH IS SCHEDULED
C     TO RECEIVE A REORDER QUANTITY ON THE DATE CONTAINED IN TRCPT(2,J)
C
C     VARIABLE NAME ASSIGNMENTS ARE AS FOLLOWS   QNOW IS THE QUANTITY
C     DEMANDED ON THE REQUISITION CURRENTLY BEING PROCESSED, VSB HOLDS
C     THE VALUE OF STOCK BOUGHT SO FAR, NOP HOLDS THE NUMBER OF ORDERS
C     PLACED SO FAR, TODAY HOLDS THE CURRENT DATE BEING SIMULATED,
C     BETA01 THROUGH BETA 20 ARE SYSTEM PARAMETERS, IWHRF HOLDS THE NUMBER
C     OF WAREHOUSE REFUSALS SO FAR, IPI HOLDS THE NUMBER OF REQUISITIONS
C     INITIALLY GIVEN PARTIAL FILLS, IFULLI HOLDS THE NUMBER OF REQNS
C     FILLED WITHOUT BACKORDERING, ANDAYS HOLDS THE NUMBER OF DAYS BEING
C     SIMULATED, NREC HOLDS THE NUMBER OF ITEM RECORDS IN THE SIMULATION,NRCPT
C     HOLDS THE NUMBER OF RECEIPTS PROCESSED SO FAR, NERRCT HOLDS THE
C     NUMBER OF ERRORS GENERATED SO FAR IN PROCESSING RECEIPTS, NERSPI
C     HOLDS THE NUMBER OF ERRORS MADE IN SPOT INVENTORIES, NSPI HOLDS
C     THE NUMBER OF PHYSICAL ITEM INVENTORIES TAKEN, VDDOHA HOLDS THE
C     VALUE IN DOLLAR DAYS OF ACTUAL INVENTORY HELD, VDDOHR HOLDS THE
C     VALUE IN DOLLAR DAYS OF RECORD INVENTORY HELD, NHIT HOLDS THE
C     NUMBER OF REQUISITIONS PROCESSED SO FAR, NERISU HOLDS THE NUMBER
C     OF ERRORS INTRODUCED SO FAR IN MAKING ISSUES, NDUES HOLDS THE
C     NUMBER OF DUES OUTSTANDING AT THE BEGINNING OF THE SIMULATION,
C     VOHR HOLDS THE CURRENT DOLLAR VALUE OF RECORD ON HAND,, VOHA HOLDS
C     THE CURRENT DOLLAR VALUE OF ACTUAL ON HAND QUANTITY, BUDGET HOLDS
C     THE NUMBER OF DOLLARS CURRENTLY AVAILABLE FOR PURCHASE OF STOCK,
C     UDB HOLDS THE NUMBER OF UNIT DAYS BACKORDERED, VALD HOLDS THE
C     DOLLAR VALUE OF DEMANDS SO FAR, VALFPI HOLDS THE DOLLAR VALUE OF STOCK
C     ISSUED WITHOUT CONSIDERING BACKORDER RELEASES.
C     INITIALIZE CONSTANTS  AND  READ IN DATA
      QNOW = 0.
      VSB = 0.
      NOP = 0
      IWHRF = 0
      IPI = 0
      IFULLI = 0
      VOH = 0.
      NRCPT = 0
      NERRCT = 0
      NERSPI = 0
      NSPI = 0
      VDDOHA = 0.
      VDDOHR = 0.
      JUMP1 = 1
      NHIT = 0
      NERISU = 0
      TODAY = 1.0
      DO 110 I = 1,100
      DO 110 J = 1,20
  110 RECORD(I,J) = 0.0
      DO 111 I = 1,2
      DO 111 J = 1,2500
  111 TRCPT(I,J) = 0.0
      RN = RND(0)
      RN = RNG(0)
      RN = RND(500)
      RN = RNG(500)
      READ 100,NREC,ANDAYS,NDUES
  100 FORMAT (I10,F10.0,I10)
      PRINT 101,NREC, ANDAYS

  101 FORMAT(10X,'NUMBER OF STOCK RECORDS  ',I10,20X,'NUMBER DAYS SIMULA
     1TED',F10.0)
      DO 102 I = 1,NREC
      READ 103,IFSC(I),IFIIN(I),(RECORD(I,J),J=2,10)
  103 FORMAT(I6,I7,1X,F10.2,6F6.0,F8.2,F5.2)
      READ 104,(RECORD(I,K),K=11,20)
  104 FORMAT(F4.2,3F4.0,F8.2,5F4.0)
  102 CONTINUE
      READ 105,BETA01,BETA02,BETA03,BETA04,BETA05,BETA06,BETA07         ,
     1BETA08, BETA09, BETA10, BETA11, BETA12, BETA13, BETA14, BETA15,
     1BETA16, BETA17, BETA18, BETA19, BETA20
  105 FORMAT (20F4.2)
      DO 106 J = 1,NDUES
  106 READ 107,TRCPT(1,J),TRCPT(2,J)
  107 FORMAT (2F10.0)
C     COMPUTE DEMAND DISTRIBUTION PARAMETERS AND TIME OF INITIAL DEMAND
      DO 151 I = 1,NREC
      TEMP1 = RECORD (I,10)*90.
      TEMP2 = RECORD (I,10)*RECORD(I,9)
      TEMP3 = RECORD(I,15)**2
      TEMP4 = TEMP3/TEMP2 + 1.0
      RECORD(I,16) = 2./TEMP4
      RECORD(I,17) = TEMP2*RECORD(I,16)/TEMP1
      IF(RECORD(I,16).GE.1.0) RECORD(I,16) = .9999
      RN = RND(1)
      RECORD(I,11) = TODAY -(1./RECORD(I,17))*ALOG(RN)
  151 CONTINUE
C     BATCH PROCESS TODAYS RECEIPTS
  248 K = 1
  202 IF(TRCPT(2,K).EQ.TODAY) GO TO 201
  203 K = K + 1
      IF(K.GE.2500) GO TO 249
      GO TO 202
  201 RN = RNG(1)
      TEMPHI = BETA02 + BETA03
      TEMP3 = TRCPT(1,K)
      I = INT(TEMP3)
      IF(RN.LE.TEMPHI) NERRCT = NERRCT + 1
      IF(RN.LE.BETA02) GO TO 204
      IF(BETA02.LT.RN.AND.RN.LE.TEMPHI) GO TO 205
      RECORD(I,4) = RECORD(I,4) + RECORD(I,7)
      RECORD(I,3) = RECORD(I,3) + RECORD(I,7)
  206 RECORD(I,5) = RECORD(I,5) - RECORD(I,7)
      VOH = VOH + (RECORD(I,7)*RECORD(I,2))
      NRCPT = NRCPT + 1
      TRCPT(1,K) = 0.0
      TRCPT(2,K) = 0.0
      RECORD(I,12) = RECORD(I,12) + 1.0
      GO TO 203
```

```
205   RECORD(I,4) = RECORD(I,4) + RECORD(I,7)
      ANREC = NREC
      TEMP = ((ANREC*(RN - BETA02))/BETA03) + 1.
      INDEX = INT(TEMP)
      RECORD(INDEX,3) = RECORD(INDEX,3) + RECORD(I,7)
      GO TO 206
204   RN = RN/BETA02
      IF(RN.LE.BETA04) GO TO 207
      Q = RECORD(I,7)
      Q = (1. - BETA05)*Q
      Q = AINT(Q)
      RECORD(I,3) = RECORD(I,3) + Q
      RECORD(I,4) = RECORD(I,4) + Q
      GO TO 206
207   Q = RECORD(I,7)
      Q = (1. + BETA06)*Q
      Q = AINT(Q)
      RECORD(I,3) = RECORD(I,3) + Q
      RECORD(I,4) = RECORD(I,4) + Q
      GO TO 206
249   CONTINUE
C     RELEASE BACKORDERS SEGMENT
      DO 250 I = 1,NREC
      IF(RECORD(I,3).GT.0..AND.RECORD(I,6).GT.0.) GO TO 251
      GO TO 250
251   IF(RECORD(I,6).LE.RECORD(I,3)) GO TO 252
      TEMP1 = RECORD(I,3)
      GO TO 256
252   TEMP1 = RECORD(I,6)
256   IF(TEMP1.LE.RECORD(I,4)) GO TO 253
      TEMP2 = TEMP1 - RECORD(I,4)
      IWHRF = IWHRF + 1
      TEMP3 = TEMP1 - TEMP2
      IF(TEMP1 - TEMP2.GT.0.) GO TO 254
257   RN = RNG(1)
      NSPI = NSPI + 1
      IF(RN.LE.BETA01) GO TO 255
      NERSPI = NERSPI + 1
      GO TO 250
255   RECORD(I,3) = RECORD(I,4)
      GO TO 250
254   RECORD(I,6) = RECORD(I,6) - TEMP3
      RECORD(I,3) = RECORD(I,3) - TEMP3
      RECORD(I,4) = RECORD(I,4) - TEMP3
      GO TO 257
253   RECORD(I,6) = RECORD(I,6) - TEMP1
      RECORD(I,4) = RECORD(I,4) - TEMP1
      RECORD(I,3) = RECORD(I,3) - TEMP1
250   CONTINUE
C     GET BUDGET SEGMENT
      IF(JUMP1.NE.1) GO TO 453
      BUDGET = 0.
      DO 451 JBUD = 1,NREC
451   BUDGET = BUDGET + (BETA20 * RECORD(JBUD,2))*(4.*(RECORD(JBUD,9)))
      PRINT 452,TODAY,BUDGET
452   FORMAT(/,10X,'BUDGET RECEIVED ON DAY',F7.0,'  IS',F14.2,'     DOLL
     1ARS')
      JUMP2 = 0
      JUMP1 = 0
453   CONTINUE
C     DAY CNE REORDER SEGMENT
      DO 457  I = 1,NREC
463   TEMP1 = RECORD(I,3) + RECORD(I,5) - RECORD(I,6)
      IF(TEMP1.GT.RECORD(I,8)) GO TO 457
      IF(BUDGET.LT.RECORD(I,2)*RECORD(I,7)) GO TO 457
      RECORD(I,5) = RECORD(I,5) + RECORD(I,7)
      VSB = VSB + RECORD(I,7)*RECORD(I,2)
      NOP = NOP + 1
      BUDGET = BUDGET - RECORD(I,2)*RECORD(I,7)
      AI = I
      J = 1

458   IF(TRCPT(1,J).EQ.0.) GO TO 459
      J = J + 1
      IF(J.EQ.2500) GO TO 460
      GO TO 458
460   PRINT 461
461   FORMAT(10X,'DAY ONE REORDER RECEIPT DUE FILE OVERLOAD')
      STOP
459   TRCPT(1,J) = AI
      TEMP1 = RECORD(I,10)*90.
C     DAY ONE BUY STOCHASTIC LEAD TIME GENERATOR
      TEMPN = 0.0
      DO 462 INDEXN = 1,12
462   TEMPN = TEMPN + RNG(1)
      TEMPN = TEMPN - 6.0
      TEMP5 = 0.0
      TEMP5 = TEMP1 + TEMP1 * .29 * TEMPN
      IF(TEMP5.LT.1.0) TEMP5 = 1.0
      TEMP5 = TEMP5 + TODAY
      TEMP5 = AINT(TEMP5)
      TRCPT(2,J) = TEMP5
      GO TO 463
457   CONTINUE
C     DEMAND AND ISSUE SEGMENT
      DO 301 I = 1,NREC
      QUIT = TODAY + 1.
326   IF(TODAY.LE.RECORD(I,11).AND.RECORD(I,11).LT.QUIT) GO TO 302
      GO TO 301
302   RN = RND(1)
      ZAP = 1.0- RECORD(I,16)
      ZAP1 = 1.0
      ISUM = 0
      TEMP = RECORD(I,16)
      QNCW = 0.
      NHIT = NHIT + 1
305   IF(RN - TEMP) 304,304,303
304   QNCW = QNOW + 1.0
      GO TO 306
303   QNCW = QNOW + 1.0
      IF(QNOW.GE.10000.) GO TO 306
      ZAP1 = ZAP1*ZAP
      IF(ZAP1.LE.1.E-60) GO TO 306
      TEMP = TEMP + ZAP1*RECORD(I,16)
      GO TO 305
306   CONTINUE
      RECORD(I,14) = RECORD(I,14) + QNOW
      RECORD(I,12) = RECORD(I,12) + 1.
      TEMP1 = RECORD(I,3) + RECORD(I,5) - RECORD(I,6) - QNOW
      IF(TEMP1.GT.RECORD(I,8)) GO TO 307
C     PROCUREMENT BUDGET CONSTRAINT SEGMENT
```

```
       IF(BUDGET.LT.RECORD(I,2)*RECORD(I,7))GO TO 454
       RECORD(I,5) = RECORD(I,5) + RECORD(I,7)
       VSB = VSB + (RECORD(I,7))*(RECORD(I,2))
       NOP = NOP + 1
       BUDGET = BUDGET - RECORD(I,2)*RECORD(I,7)
       AI = I
       J = 1
322    IF(TRCPT(1,J).EQ.0.) GO TO 323
       J = J + 1
       IF(J.GE.2500) GO TO 324
       GO TO 322
454    IF(JUMP2.EQ.0) GO TO 455
       GO TO 307
455    PRINT 456 , TODAY
456    FORMAT(/,10X,'BUDGET CONSTRAINT ACTIVE ON DAY',F10.0)
       JUMP2 = 1
       GO TO 307
324    PRINT 325
325    FORMAT(10X,'RECEIPT DUE FILE OVERLOAD')
       STOP
323    TRCPT(1,J) = AI
       TEMP1 = (RECORD(I,10))*90.
C      STOCHASTIC LEAD TIME GENERATOR SEGMENT
       TEMPN = 0.0
       DO 327 INDEXN = 1,12
327    TEMPN = TEMPN + RNG(1)
       TEMPN = TEMPN - 6.0
       TEMP5 = 0.0
       TEMP5 = TEMP1 + TEMP1*(.29)*TEMPN
       IF(TEMP5.LT.1.0) TEMP5 = 1.
       TEMP5 = TEMP5 + TODAY
       TEMP5 = AINT(TEMP5)
       TRCPT(2,J) = TEMP5
       GO TO 306
307    IF(QNOW.LE.RECORD(I,3)) GO TO 308
       TEMP1 = RECORD(I,3)
       GO TO 309
308    TEMP1 = QNOW
309    RECORD(I,6) = RECORD(I,6) + QNOW - TEMP1
       IF(TEMP1.LE.RECORD(I,4)) GO TO 310
       TEMP2 = RECORD(I,4) - TEMP1
       TEMP2 = TEMP1 - TEMP2
       RECORD(I,6) = RECORD(I,6) + TEMP2
       IWHRF = IWHRF + 1
       NSPI = NSPI + 1
       RECORD(I,3) = RECORD(I,3) - TEMP3
       RN = RNG(1)
       IF(RN.LE.BETA01) GO TO 311
       NERSPI = NERSPI + 1
       GO TO 312
310    RECORD(I,3) = RECORD(I ,3) - TEMP1
       TEMP3 = TEMP1
       TEMP2 = 0.
       GO TO 312
311    RECORD(I,3) = RECORD ( I,4)
312    RN = RNG(1)
       IF(RN.LE.BETA07) GO TO 313
       RECORD(I,4) = RECORD(I,4) - TEMP3
       GO TO 321
313    RN = RN/BETA07
       NERISU = NERISU + 1
       IF(0..LE.RN.AND.RN.LE.BETA08) GO TO 314
       TEMP4 = BETA08 + BETA09
       IF(BETA08.LT.RN.AND.RN.LE.TEMP4) GO TO 317
       GO TO 321
317    RN = (RN - BETA08)/BETA09
       TEMPB = BETA10 + BETA11
       IF(RN.LE.BETA10) GO TO 318
       IF(RN.LE.TEMPB) GO TO 319
       TEMP3 = TEMP3*(1. + BETA16)
       GO TO 320
318    TEMP3 = TEMP3*(1. + BETA14)
       GO TO 320
319    TEMP3 = TEMP3*(1. + BETA15)
       GO TO 320
314    RN = RN/BETA08
       IF(RN.LE.BETA12) GO TO 315
       TEMPA = BETA12 + BETA13
       IF(RN.LE.TEMPA) GO TO 316
       TEMP3 = TEMP3*(1. - BETA19)
       GO TO 320
316    TEMP3 = TEMP3 * (1. - BETA18)
       GO TO 320
315    TEMP3 = TEMP3 * (1. - BETA17)
320    TEMP3 = AINT(TEMP3)
       RECORD(I,4) = RECORD(I,4) - TEMP3
       IF(RECORD(I,4).LT.0.) RECORD(I,4) = 0.
321    RECORD(I,13) = RECORD(I,13) + TEMP3
       IF(QNOW.NE.TEMP3.AND.TEMP3.GT.0.) IPI = IPI + 1
       IF(TEMP3.EQ.QNOW) IFULLI = IFULLI + 1
       RN = RND(1)
       TEMPA = -(1.0/RECORD(I,17))*ALOG(RN)
       RECORD(I,11) = RECORD(I,11) + TEMPA
       GO TO 326
301    CONTINUE
C      DAILY UPDATE SEGMENT
       DO 351 I = 1,NREC
       IF(RECORD(I,4).LT.0.) RECORD(I,4) = 0.
       IF(RECORD(I,3).LT.0.) RECORD(I,3) = 0.
       IF(RECORD(I,6).GT.0.) RECORD(I,18) = RECORD(I,18) + RECORD(I,6)
       VDDOHA = VDDOHA + RECORD(I,4)*RECORD(I,2)
       VDDOHR = VDDOHR + RECORD(I,3)*RECORD(I,2)
351    CONTINUE
C      SPECIAL REPORTS SECTION
       IF(TODAY.EQ.365.) JUMP1 = 1
       IF(TODAY.EQ.730.) JUMP1 = 1
       IF(TODAY.EQ.1095.)JUMP1 = 1
       IF(TODAY.EQ.1460.) JUMP1 = 1
       IF(JUMP1.EQ.1) GO TO 401
C      DAY END SECTION
       IF(TODAY.GE.ANDAYS) GO TO 401
400    TODAY = TODAY + 1.
       GO TO 248
C      REPORT GENERATOR SEGMENT
401    PRINT 402
402    FORMAT(1H1,////,20X,'REPORT OF SIMULATION')
       DO 403 I = 1,NREC
       PRINT 404,IFSC(I),IFIIN(I),(RECORD(I,J),J=2,20)
404    FORMAT(//,I6,I7,9G10.3,/,10G10.3)
403    CONTINUE
```

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      PRINT 405, ANDAYS,NREC
405   FORMAT(//,10X,'NUMBER OF DAYS SIMULATED',F6.0,' ,   NUMBER OF ITEM
     1S',G10.4)
      PRINT 406, NOP,VSB,TODAY,IWHRF,IPI,IFULLI,NHIT
406   FORMAT(//7G14.7)
      PRINT 407,BETA01,BETA02,BETA03,BETA04,BETA05,BETA06,BETA07,BETA08,
     1BETA09,BETA10,BETA11,BETA12,BETA13,BETA14,BETA15,BETA16,BETA17,BET
     2A18,BETA19,BETA20
407   FORMAT(/,10X,'PARAMETER LIST',20F4.2)
      PRINT 408, VDDOHA,VDDOHR
408   FORMAT(/,10X,'VDDOHA IS', G20.7,', VDDOHR IS',G20.7)
      UDB = 0.
      VALD = 0.
      VFPI = 0.
      VOHA = 0.0
      VOHR = 0.0
      DO 412 I = 1,NREC
      VOHA = VOHA + (RECORD(I,4)*RECORD(I,2))
      VOHR = VOHR + (RECORD(I,3)*RECORD(I,2))
      UDB = UDB + RECORD(I,18)
      VALD = VALD + RECORD(I,14)*RECORD(I,2)
      VFPI = VFPI + RECORD(I,13)*RECORD(I,2)
412   CONTINUE
      PRINT 413,VOHA,VOHR
413   FORMAT(//,10X,'DOLLAR VALUE OF ACTUAL ON HAND STOCK IS $',F14.2,/,
     110X,'DOLLAR VALUE OF RECORD ON HAND STOCK IS $',F14.2)
      PRINT 409,NRCPT,NSPI
409   FORMAT(/,10X,3G10.4)
      PRINT 410, NERRCT,NERSPI,NERISU
410   FORMAT(/,10X,G10.4)
      PRINT 416, UDB
416   FORMAT(10X,'NUMBER OF UNIT DAYS BACKORDERED THUS FAR IS ',G14.7)
      PRINT 417, VALD,VFPI
417   FORMAT(10X,'VALUE OF DEMANDS THUS FAR IS $',F20.2,/,10X,'VALUE OF
     1STOCK ISSUED THUS FAR WITHOUT CONSIDERING BACKORDER RELEASES IS $'
     2,F20.2)
      TODAY = TODAY + 1.
      IF(TODAY.LE.ANDAYS) GO TO 248
      PRINT 411, NDUES
411   FORMAT(/,G10.4,'DUES AT BEGINNING OF THE SIMULATION')
      DO 414 J = 1,624,4
414   PRINT 415,TRCPT(1,J),TRCPT(2,J),TRCPT(1,J+1),TRCPT(2,J+1),TRCPT(1,
     1J+2),TRCPT(2,J+2),TRCPT(1,J+3),TRCPT(2,J+3)
415   FORMAT(5X,F10.0,F10.0,5X,F10.0,F10.0,5X,F10.0,F10.0,5X,F10.0,F10.0
     1)
      STOP
      END
      FUNCTION  RND(N)
      NR1 = N
      IF(NR1)11,11,21
11    IX1 = 30517
      NR1 = NR1 + 1
21    DO 49 I = 1,NR1
      IY1 = IX1*65539
      IF(IY1) 7,8,8
7     IY1 = IY1 + 2147483647 + 1
8     RND = IY1
      RND = RND*.4656613 E-9
49    IX1 = IY1
      RETURN
      END
      FUNCTION   RNG(N)
      NR = N
      IF(NR) 10,10,20
10    IX = 30517
      NR = NR + 1
20    DO 50 I = 1,NR
      IY = IX*65539
      IF(IY) 5,6,6
5     IY = IY + 2147483647 + 1
6     RNG = IY
      RNG = RNG * .4656613 E-9
50    IX = IY
      RETURN
      END
       100       1825.          13
  48209651139.      48.30 1160. 1160. 1664.      0.   832.  2719.   831.45 4.00
 .00  0.  0.  0.   651.78  0.   0.    0.    0.   0.
  47102774656.       1.66 1807. 1807.47434.      0.23717.46255.23716.59 2.50
 .00  0.  0.  0.16153.60  0.   0.    0.    0.   0.
  61100569349. 401091.40    1.    1.      0.     0.     1.     0.      .28 3.00
 .00  0.  0.  0.      .88  0.   0.    0.    0.   0.
  20908507777.     649.00  219.  219.      0.     0.    71.   167.    70.92 5.90
 .00  0.  0.  0.   122.38  0.   0.    0.    0.   0.
  47102893513.       3.0624848.24848.     0.     0.13338.22124.13337.59 3.40
 .00  0.  0.  0.12984.13  0.   0.    0.    0.   0.
  45303948472.     226.45   51.   51.   232.     0.   116.   237.   115.30 3.20
 .00  0.  0.  0.   100.15  0.   0.    0.    0.   0.
  20905433595.      83.03  282.  282.   606.     0.   202.   760.   201.06 5.70
 .00  0.  0.  0.   381.18  0.   0.    0.    0.   0.
  20503954300.     225.00  125.  125.    82.     0.    82.   197.    81.84 3.90
 .00  0.  0.  0.    87.85  0.   0.    0.    0.   0.
  59252582945.      53.30    0.    0.   594.    21.   297.   478.   296.72 2.40
 .00  0.  0.  0.   256.89  0.   0.    0.    0.   0.
  20103440728.     456.00  102.  102.      0.     0.    53.    55.    52.63 2.40
 .00  0.  0.  0.    35.54  0.   0.    0.    0.   0.
  41402898801.     265.97   93.   93.    65.     0.    65.   103.    64.75 3.90
 .00  0.  0.  0.    89.63  0.   0.    0.    0.   0.
  49402618415.      26.00 1061. 1061.      0.     0.   578.  1659.   577.72 2.90
 0.   0.  0.  0.   424.33 0.0   0.    0.    0.   0.
  42203009929.    1040.00   53.   53.      0.     0.    21.    40.    20.05 3.00
 0.   0.  0.  0.    13.92  0.   0.    0.    0.   0.
  61407319144.       3.6618044.18044.     0.     0.  5763.12765.  5762.05 2.90
 0.   0.  0.  0.  3923.24  0.   0.    0.    0.   0.
  41309139430.     464.75   00.    0.      0.    22.    28.    19.    27.52 2.80
 0.   0.  0.  0.    32.17  0.   0.    0.    0.   0.
  46203903729.    1547.83    0.    0.      0.    17.     8.     0.     7.03 6.30
 0.   0.  0.  0.    81.20  0.   0.    0.    0.   0.
  66251968776.      99.50    0.    0.      0.   255.    90.   125.    90.00 3.00
 0.   0.  0.  0.    79.29  0.   0.    0.    0.   0.
  28153432796.    3386.41    5.    5.      0.     0.     6.     0.     5.69 3.30
 C.   0.  0.  0.    26.99  0.   0.    0.    0.   0.
  20903684787.     218.34  192.  192.      0.     0.    93.    63.    92.53 3.10
 0.   0.  0.  0.   116.75  0.   0.    0.    0.   0.
  43203187236.     511.25  174.  174.      0.     0.    41.    95.    40.91 3.90
 0.   0.  0.  0.    41.04  0.   0.    0.    0.   0.
  43301630328.      67.69  107.  107.      0.     0.   128.   443.   127.03 3.60
 0.   0.  0.  0.   132.43  0.   0.    0.    0.   0.
  43200868592.     809.00    0.    0.      0.     6.    12.    11.    11.63 4.80
 0.   0.  0.  0.    25.84  0.   0.    0.    0.   0.
```

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44203903763.      48.22    0.     0.      0. 172.  148.  377.  147.36 3.80
0.   0.   0.   0.  109.93  0.  0.    0.    0.  0.
20408001411.       1.1466115.66115.       0.    0.18239.26339.18238.31 2.70
0.   0.   0.   0.18897.13  0.  0.    0.    0.  0.
67303566867.       7.80 7666.7666.        0.   0. 1226. 9085. 1225.47 6.90
0.   0.   0.   0. 1826.27  0.  0.    0.    0.  0.
10756918345.     148.00  181.   181.      0.    0.   75.  191.   74.63 3.00
0.   0.   0.   0.   66.18  0.  0.    0.    0.  0.
34390888986.       2.69 1285.  1285.      0.    0. 3019. 7969. 3018.50 3.40
0.   0.   0.   0. 1407.71  0.  0.    0.    0.  0.
28253836445.     821.00   53.    53.      0.    0.   16.   50.   15.17 4.60
0.   0.   0.   0.   16.07  0.  0.    0.    0.  0.
66808477621.     423.83    0.     0.      0. 149.    1.    0.     .81 2.90
0.   0.   0.   0.    2.39  0.  0.    0.    0.  0.
67303417842.       4.25 3013.  3013.      0.    0. 1424. 9244. 1423.63 5.60
0.   0.   0.   0. 1737.41  0.  0.    0.    0.  0.
45108999837.      80.00 1094.  1094.      0.    0.  290.  265.  290.00 2.00
0.   0.   0.   0.  144.56  0.  0.    0.    0.  0.
59400803932.     241.00   52.    52.      0.    0.   36.   71.   35.95 2.60
0.   0.   0.   0.   26.33  0.  0.    0.    0.  0.
47302937481.       1.1613752.13752.       0.    0. 7602.16816. 7601.81 3.90
0.   0.   0.   0.12678.96  0.  0.    0.    0.  0.
44103779737.      38.00   77.    77.      0.    0.  185.  413.  184.16 3.40
0.   0.   0.   0.  239.81  0.  0.    0.    0.  0.
61053189250.     250.75  104.   104.      0.    0.   43.   82.   42.66 3.00
0.   0.   0.   0.   46.54  0.  0.    0.    0.  0.
68302646748.      56.56 1013.  1013.      0.    0.  264.  467.  263.78 2.90
0.   0.   0.   0.  266.08  0.  0.    0.    0.  0.
66808666136.    2100.00    0.     0.      0.    7.    3.    0.    2.80 3.40
0.   0.   0.   0.    9.26  0.  0.    0.    0.  0.
44108682862.      80.00  160.   160.      0.    0.   89.  248.   88.39 3.00
0.   0.   0.   0.   78.74  0.  0.    0.    0.  0.
28254466643.     182.00  103.   103.      0.    0.   41.  131.   40.52 4.00
0.   0.   0.   0.   42.50  0.  0.    0.    0.  0.
34332776578.     529.33  135.   135.      0.    0.   29.   71.   28.53 3.60
0.   0.   0.   0.   27.52  0.  0.    0.    0.  0.
20409690915.    1272.47    0.     0.      0.    6.    6.    0.    5.25 4.30
0.   0.   0.   0.   37.23  0.  0.    0.    0.  0.
34398664149.       3.00 7640.  7640.      0.    0. 2520. 7966. 2519.06 3.70
0.   0.   0.   0. 2457.43  0.  0.    0.    0.  0.
59905046036.     176.00    0.     0.      0.   35.   26.   62.   25.56 2.90
0.   0.   0.   0.   21.85  0.  0.    0.    0.  0.
20400551128.     284.19    0.     0.      0.   27.   18.   21.   17.77 4.00
0.   0.   0.   0.   25.01   0.   0.   0.    0.    0.
31109873724.      21.53 1010.  1010.      0.    0.  272. 1379.  271.78 4.70
0.   0.   0.   0.  375.57  0.  0.    0.    0.  0.
44103720897.       3.22 2767.  2767.      0.    0. 1567. 6595. 1566.14 4.00
0.   0.   0.   0. 1544.79  0.  0.    0.    0.  0.
47309539500.     120.00    1.     1.      0.    0.   50.   51.   49.50 3.80
0.   0.   0.   0.   61.03  0.  0.    0.    0.  0.
59403512226.      24.94  506.   506.      0.    0.  208.  894.  207.38 4.10
0.   0.   0.   0.  302.92  0.  0.    0.    0.  0.
59402155959.       9.00 2040.  2040.      0.    0.  681. 2445.  680.14 3.50
0.   0.   0.   0.  296.29  0.  0.    0.    0.  0.
42408987088.     147.50   66.    66.      0.    0.   41.   95.   40.34 3.60
0.   0.   0.   0.   51.90  0.  0.    0.    0.  0.  0.
48209651139.      48.30 1160.  1160.      0.    0.  832. 2719.  831.45 4.00
.00  0.   0.   0.  651.78  0.  0.    0.    0.  0.
47102774656.       1.66 1807.  1807.      0.    0.23717.46255.23716.59 2.50
.00  0.   0.   0.16153.60  0.  0.    0.    0.  0.
61100569349. 401091.40    1.     1.      0.    0.    1.    0.     .28 3.00
.00  0.   0.   0.     .88  0.  0.    0.    0.  0.
20908507777.     649.00  219.   219.      0.    0.   71.  167.   70.92 5.90
.00  0.   0.   0.  122.38  0.  0.    0.    0.  0.
47102893513.       3.0624848.24848.       0.    0.13338.22124.13337.59 3.40
.00  0.   0.   0.12984.13  0.  0.    0.    0.  0.
45303948472.     226.45   51.    51.      0.    0.  116.  237.  115.30 3.20
.00  0.   0.   0.  100.15  0.  0.    0.    0.  0.
20905433595.      83.03  282.   282.      0.    0.  202.  760.  201.06 5.70
.00  0.   0.   0.  381.18  0.  0.    0.    0.  0.
20503954300.     225.00  125.   125.      0.    0.   82.  197.   81.84 3.90
.00  0.   0.   0.   87.85  0.  0.    0.    0.  0.
59252582945.      53.30    0.     0.      0.   21.  297.  478.  296.72 2.40
.00  0.   0.   0.  256.89  0.  0.    0.    0.  0.
20103440728.     456.00  102.   102.      0.    0.   53.   55.   52.63 2.40
.00  0.   0.   0.   35.54  0.  0.    0.    0.  0.
41402898801.     265.97   93.    93.      0.    0.   65.  103.   64.75 3.90
.00  0.   0.   0.   89.63  0.  0.    0.    0.  0.
49402618415.      26.00 1061.  1061.      0.    0.  578. 1659.  577.72 2.90
0.   0.   0.   0.  424.33 0.0  0.    0.    0.  0.
42203009929.    1040.00   53.    53.      0.    0.   21.   40.   20.05 3.00
0.   0.   0.   0.   13.92  0.  0.    0.    0.  0.
61407319144.       3.6618044.18044.       0.    0. 5763.12765. 5762.05 2.90
0.   0.   0.   0. 3923.24  0.  0.    0.    0.  0.
41309139430.     464.75   00.     0.      0.   22.   28.   19.   27.52 2.80
0.   0.   0.   0.   32.17  0.  0.    0.    0.  0.
46203903729.    1547.83    0.     0.      0.   17.    8.    0.    7.03 6.30
0.   0.   0.   0.   81.20  0.  0.    0.    0.  0.
66251968776.      99.50    0.     0.      0.  255.   90.  125.   90.00 3.00
0.   0.   0.   0.   79.29  0.  0.    0.    0.  0.
28153432796.    3386.41    5.     5.      0.    0.    6.    0.    5.69 3.30
0.   0.   0.   0.   26.99  0.  0.    0.    0.  0.
20903684787.     218.34  192.   192.      0.    0.   93.   63.   92.53 3.10
0.   0.   0.   0.  116.75  0.  0.    0.    0.  0.
43203187236.     511.25  174.   174.      0.    0.   41.   95.   40.91 3.90
0.   0.   0.   0.   41.04  0.  0.    0.    0.  0.
43301630328.      67.69  107.   107.      0.    0.  128.  443.  127.03 3.60
0.   0.   0.   0.  132.43  0.  0.    0.    0.  0.
43200868592.     809.00    0.     0.      0.    6.   12.   11.   11.63 4.90
0.   0.   0.   0.   25.84  0.  0.    0.    0.  0.
44203903763.      48.22    0.     0.      0. 172.  148.  377.  147.36 3.80
0.   0.   0.   0.  109.93  0.  0.    0.    0.  0.
20408001411.       1.1466115.66115.       0.    0.18239.26339.18238.31 2.70
0.   0.   0.   0.18897.13  0.  0.    0.    0.  0.
67303566867.       7.80 7666.7666.        0.   0. 1226. 9085. 1225.47 6.90
0.   0.   0.   0. 1826.27  0.  0.    0.    0.  0.
10756918345.     148.00  181.   181.      0.    0.   75.  191.   74.63 3.00
0.   0.   0.   0.   66.18  0.  0.    0.    0.  0.
34390888986.       2.69 1285.  1285.      0.    0. 3019. 7969. 3018.50 3.40
0.   0.   0.   0. 1407.71  0.  0.    0.    0.  0.
28253836445.     821.00   53.    53.      0.    0.   16.   50.   15.17 4.60
0.   0.   0.   0.   16.07  0.  0.    0.    0.  0.
66808477621.     423.83    0.     0.      0. 149.    1.    0.     .81 2.90
0.   0.   0.   0.    2.39  0.  0.    0.    0.  0.
67303417842.       4.25 3013.  3013.      0.    0. 1424. 9244. 1423.63 5.60
0.   0.   0.   0. 1737.41  0.  0.    0.    0.  0.
45108999837.      80.00 1094.  1094.      0.    0.  290.  265.  290.00 2.00
0.   0.   0.   0.  144.56  0.  0.    0.    0.  0.
59400803932.     241.00   52.    52.      0.    0.   36.   71.   35.95 2.60
0.   0.   0.   0.   26.33  0.  0.    0.    0.  0.
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  47302937481.          1.1613752.13752.    0.    0. 7602.16816. 7601.81 3.90
  0.  0.  0.   0.12678.96  0.  0.  0.   0.  0.
  44103779737.       38.00   77.    77.    0.    0.   185.   413.   184.16 3.40
  0.  0.  0.  0.    239.81  0.  0.  0.   0.  0.
  61053189250.      250.75  104.   104.    0.    0.    43.    82.    42.66 3.00
  0.  0.  0.  0.     46.54  0.  0.  0.   0.  0.
  68302646748.       56.56 1013.  1013.    0.    0.   264.   467.   263.78 2.90
  0.  0.  0.  0.    266.08  0.  0.  0.   0.  0.
  66808666136.     2100.00    0.     0.    0.    7.     3.     0.     2.80 3.40
  0.  0.  0.  0.      9.26  0.  0.  0.   0.  0.
  44108682862.       80.00  160.   160.    0.    0.    89.   248.    88.39 3.00
  0.  0.  0.  0.     78.74  0.  0.  0.   0.  0.
  28254466643.      182.00  103.   103.    0.    0.    41.   131.    40.52 4.00
  0.  0.  0.  0.     42.50  0.  0.  0.   0.  0.
  34332776578.      529.33  135.   135.    0.    0.    29.    71.    28.53 3.60
  0.  0.  0.  0.     27.52  0.  0.  0.   0.  0.
  20409690915.     1272.47    0.     0.    0.    6.     6.     0.     5.25 4.30
  0.  0.  0.  0.     37.23  0.  0.  0.   0.  0.
  34398664149.        3.00 7640.  7640.    0.    0.  2520.  7966.  2519.06 3.70
  0.  0.  0.  0.   2457.43  0.  0.  0.   0.  0.
  59905046036.      176.00    0.     0.    0.   35.    26.    62.    25.56 2.90
  0.  0.  0.  0.     21.85  0.  0.  0.   0.  0.
  20400551128.      284.19    0.     0.    0.   27.    18.    21.    17.77 4.00
  0.  0.  0.  0.     25.01   0.    0.  0.   0.   0.
  31109873724.       21.53 1010.  1010.    0.    0.   272.  1379.   271.78 4.70
  0.  0.  0.  0.    375.57  0.  0.  0.   0.  0.
  44103720897.        3.22 2767.  2767.    0.    0.  1567.  6595.  1566.14 4.00
  0.  0.  0.  0.   1544.79  0.  0.  0.   0.  0.
  47309539500.      120.00    1.     1.    0.    0.    50.    51.    49.50 3.80
  0.  0.  0.  0.     61.03  0.  0.  0.   0.  0.
  59403512226.       24.94  506.   506.    0.    0.   208.   894.   207.38 4.10
  0.  0.  0.  0.    302.92  0.  0.  0.   0.  0.
  59402155959.        9.00 2040.  2040.    0.    0.   681.  2445.   680.14 3.50
  0.  0.  0.  0.    296.29  0.  0.  0.   0.  0.
  42408987088.      147.50   66.    66.    0.    0.    41.    95.    40.34 3.60
  0.  0.  0.  0.     51.90  0.  0.  0.   0.  0.   0.
0.970.030.010.500.060.080.020.330.330.660.250.660.170.080.180.500.060.200.601.00
        1.       196.
        1.       287.
        2.        63.
        2.       154.
        6.       143.
        6.       233.
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        9.        65.
        9.       155.
       11.       338.
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13. ABSTRACT

Changes in costs and in several effectiveness measures due to the introduction of errors into inventory records are investigated using Monte Carlo computer simulation of a multiple item, single warehouse, single inventory manager inventory system operating under a procurement budget constraint. Demands are generated using a "stuttering Poisson" stochastic process and transactions are processed on a daily basis. Parameters for the stochastic processes are obtained from line item input data by the method of moments. Stock is reordered using U. S. Navy UICP decision rules; stochastic lead times are generated for each order. Discrepancies of various types are introduced at rates reflecting estimates obtained from a large naval supply center. Changes in costs due to discrepant records are found to be significantly large. Comments are offered on the selection of a measure of effectiveness and its relationship to the decision making process. Suggestions are made for subsequent research.

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SIMULATION						
MEASURE OF EFFECTIVENESS						
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